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Proposed scientific support to the Land Vehicle Crew Training System (LVCTS) project requirements definition

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Defence R&D Canada
Technical Memorandum
DRDC Toronto TM 2011-156
January 2013

Canada

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The work documented in this report was conducted under Thrust 14dn, Virtual Reality for Team Training

Abstract

The Land Vehicle Crew Training System (LVCTS) is a proposed acquisition of a variety of armoured vehicle simulators for training within the Canadian Forces. The Directorate of Land Requirements (DLR) has published a Letter of Interest (LOI) to solicit input from industry, but DLR has requested advice from Defence Research and Development Canada (DRDC) Toronto to provide evidence based determination of the simulator requirements. DRDC Toronto has proposed 5 tasks that could be undertaken to clarify requirements, based on information provided in the LOI, suitable for inclusion in a Request for Proposal. The tasks include: preliminary Training Needs Analysis; an assessment of the expected simulator effectiveness; an assessment of motion base requirements; an evaluation of visual display requirements; and, an assessment of auditory noise requirements. Estimates of the time and cost to complete these tasks are included in the report for DLR consideration.

Résumé

Le système d’entraînement des équipages des véhicules terrestres (SEE VT) constitue une proposition d’acquisition d’une variété de simulateurs de véhicules blindés destinés à l’entraînement au sein des Forces canadiennes. La Direction des besoins en ressources terrestres (DBRT) a publié une déclaration d’intérêt afin d’obtenir des renseignements de la part de l’industrie tout en demandant des conseils à Recherche et développement pour la défense Canada (RDDC) Toronto afin que celle-ci lui fournisse des observations factuelles à l’égard des exigences en matière de simulateurs. RDDC Toronto a proposé cinq tâches susceptibles d’être entreprises pour clarifier les exigences, fondées sur les renseignements contenus dans la lettre d’intérêt, pouvant être incluses dans une demande de proposition. Ces tâches sont les suivantes : l’analyse préliminaire des besoins en matière d’instruction, l’évaluation de l’efficacité attendue des simulateurs, l’évaluation des exigences fondées sur le mouvement, l’évaluation des exigences en matière de visualisation et l’évaluation des exigences en matière de bruits auditifs. Des estimations du temps et des coûts pour accomplir ces tâches se trouvent dans le rapport à des fins d’analyse par la DBRT.

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Executive summary

Proposed scientific support to the Land Vehicle Crew Training System (LVCTS) project requirements definition

Cain, Brad; Zotov, Vlad; DRDC Toronto TM 2011-156; Defence R&D Canada – Toronto; January 2013.

Background: The Canadian Forces (CF) Directorate of Land Requirements (DLR) is considering the acquisition of a system of simulators for training armoured vehicle operations under the Land Vehicle Crew Training System (LVCTS) project. DLR has published a Letter of Interest (LOI) to solicit input from industry, identifying broad characteristics that the LVCTS system should be capable of performing in order to meet the envisioned training demands. DLR requested the assistance of Defence Research and Development Canada (DRDC) Toronto to provide advice on identifying quantifiable requirements based on the LOI that would be suitable for inclusion in a Request for Proposal.

Approach: DRDC Toronto reviewed DLR's published LOI and met with LVCTS project staff to discuss the intent of the project. Qualification Standards and Training Plans for several military armoured vehicle occupations were reviewed to identify high level needs that the simulator system would be addressing.

Results: The reviewed project documents and discussions lead to the proposal of 5 scientific or technical tasks that DRDC Toronto felt were relevant to the project and that DRDC Toronto had expertise to either oversee or conduct the required work. The tasks are:

1. A high level Job/Training Needs Analysis to identify the overall goals in the training tasks, methods of achieving the goals and the information flow requirements.

2. An experimental study to predict the range of tasks that each of the envisioned simulators would be suitable for in order to determine to number of each style of simulator required.

3. An experimental study of the motion base requirements necessary to support learning in land vehicle operations.

4. An analytic assessment of the visual display systems required to meet the training objectives for the envisioned tasks.

5. An experimental study of the need for noise in the simulations and its effect on learning to assess whether or not the risk of representative vehicle noise is warranted in a training simulator.

Estimates were made of the time and cost of each of these tasks so that DLR could make a judgement of whether or not there was sufficient benefit to completing the tasks to warrant the associated costs. The total cost for all 5 tasks was estimated to be between $500,000 and $750,000CAD, and would take approximately 12 months, although the duration could be reduced considerably if tasks were conducted in parallel.

Significance: The proposed tasks would provide DLR with information that would help them to be an informed consumer by defining the appropriate requirements for the simulator system to meet the training objectives. There is a tendency to acquire as much “fidelity” in a simulator as is affordable because of a misguided assumption that “more fidelity” equates to “more training benefit”, a phenomenon termed Naïve Realism; however, there is considerable evidence that training may effectively be achieved with cost effective and affordable simulators that have been specified based on behavioural, performance based criteria that lead to training effectiveness.

Future Plans: The report will be presented to DLR LVCTS staff for consideration. If DLR elects to pursue any of the proposed tasks, DRDC Toronto will provide scientific oversight for contracted work or conduct experiments as appropriate.

Sommaire

Proposed scientific support to the Land Vehicle Crew Training System (LVCTS) project requirements definition

Cain, Brad; Zotov, Vlad ; DRDC Toronto TM 2011-156 ; R & D pour la défense Canada – Toronto; janvier 2013.

Contexte : La Direction des besoins en ressources terrestres (DBRT) des Forces canadiennes (FC) envisage acquérir un système de simulateurs destiné à des opérations d'entraînement à bord de véhicules blindés dans le cadre du projet du système d'entraînement des équipages des véhicules terrestres (SEE VT). La DBRT a publié une déclaration d'intérêt afin d'obtenir des renseignements de la part de l'industrie, indiquant les principales caractéristiques que le SEE VT devrait être en mesure de réaliser pour satisfaire aux demandes prévues en matière d'entraînement. La DBRT a demandé à Recherche et développement pour la défense Canada (RDDC) Toronto des conseils sur l'identification de besoins quantifiables fondés sur la déclaration d'intérêt pouvant être inclus dans une demande de proposition.

Approche : RDDC Toronto a examiné la déclaration d'intérêt de la DBRT et a rencontré le personnel du projet SEE VT afin de discuter de l'intention du projet. Les normes de qualification et les plans d'instruction de plusieurs groupes professionnels des véhicules blindés ont été examinés afin de déterminer les besoins de haut niveau que le système de simulateurs doit traiter.

Résultats : Les discussions et les documents entourant le projet révisé ont conduit à la proposition de cinq tâches techniques ou scientifiques que RDDC Toronto considéraient pertinentes pour le projet et et pour lesquelles elle estime avoir l'expertise nécessaire pour superviser les travaux ou mener les expériences. Ces tâches sont les suivantes :

1. Une analyse des besoins de haut niveau en matière d'instruction/d'emploi afin d'identifier les objectifs généraux des tâches d'instruction, les moyens de réaliser les objectifs et les exigences relatives au cheminement des renseignements.

2. Une étude expérimentale visant à prévoir la gamme de tâches pour lesquelles chacun des simulateurs conviendrait afin de déterminer le nombre requis de chaque type de simulateur.

3. Une étude expérimentale des exigences fondées sur le mouvement, requises pour appuyer l'apprentissage dans le cadre d'opérations à bord de véhicules terrestres.

4. Une évaluation analytique des exigences en matière de visualisation visant à satisfaire aux objectifs de formation relatifs aux tâches prévues.

5. Une étude expérimentale du besoin de bruit lors des simulations et de ses répercussions sur l'apprentissage afin d'évaluer si le risque de bruit représentatif d'un véhicule est justifié dans un simulateur d'entraînement.

Des estimations du temps et des coûts pour accomplir chacune de ces tâches ont été réalisées de manière que la DBRT puisse juger si le fait de mener les tâches à terme comportaient

suffisamment d'avantages pour en justifier les coûts. Les cinq tâches ont été évaluées entre 500 000 et 750 000 dollars canadiens, échelonnées sur douze mois environ, bien que la durée pourrait être considérablement réduite si les tâches étaient menées concurremment.

Portée : Les tâches proposées fourniraient à la DBRT des renseignements qui l'aideraient à être un consommateur averti en définissant les exigences appropriées pour que le système de simulateurs atteigne les objectifs de l'entraînement. Il existe une tendance qui vise à acquérir, dans un simulateur, autant de « fidélité » que possible en raison d'une hypothèse erronée voulant que « plus il y a de fidélité, meilleur est l'entraînement », un phénomène appelé réalisme naïf. Toutefois, il est vrai que l'entraînement peut être exécuté à l'aide de simulateurs économiques et abordables qui reposent sur des critères particuliers de comportement et de rendement menant à l'efficacité de l'entraînement.

Perspectives : Le rapport sera remis au personnel du SEE VT de la DBRT à des fins d'analyse. Si la DBRT choisit d'entreprendre l'une ou l'autre des tâches proposées, RDDC Toronto assurera la supervision scientifique du travail ou mènera elle-même les expériences, le cas échéant.

Abbreviations

ALSC	Army Learning Support Centre
CAD	Canadian Dollars
CAVE	Cave Automatic Virtual Environment
CCV	Close Combat Vehicle
CF	Canadian Forces
CFB	Canadian Forces Base
CTC	Combat Training Centre (CFB Gagetown)
DLR	Directorate of Land Requirements
DRDC	Defence Research and Development Canada
DSTL	Directorate Science and Technology Land
FFT	Fast Fourier Transform
HEEC	Human Effectiveness Experimentation Centre
HF	Human Factors
HMD	Head Mounted Display
IR	Infra Red
LAV	Light Armoured Vehicle
LAVCGT	Light Armoured Vehicle Crew Gunnery Trainer
LOI	Letter of Interest
LVCTS	Land Vehicle Crew Training System
NATO	North Atlantic Treaty Organization
PM	Project Manager
QS	Qualification Standard
SME	Subject Matter Expert
TAPV	Tactical Armoured Patrol Vehicle
TD	Temporary Duty
TDO	Training Development Officer
TNA	Training Needs Analysis
TOT	Transfer of Training
TP	Training Plan

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1 Background

The Land Vehicle Crew Training System (LVCTS) is a proposed acquisition of a variety of armoured vehicle simulators for the Canadian Forces (CF). The objective of the project is to provide simulation based training to augment field training for individual and collective tasks. The intent is to use simulation where it is a cost-effective alternative to live training; the implication of this is that this will also have a beneficial effect on “environmental impact” resulting from reduced live training that may be accomplished through simulation.

Currently, the project is focussing on the Light Armoured Vehicle (LAV) III, Leopard 2 A6M, Close Combat Vehicle (CCV) and Tactical Armoured Patrol Vehicle (TAPV), although the LVCTS project has adopted a modular architecture with the intention of providing ready integration of future land training simulators. The simulators are proposed to be housed in purpose-built facilities at 5 armoured training bases across Canada. The envisioned project will cost several hundred million dollars in total. Although not yet approved, the project is expected to receive definition approval in the fall of Fiscal Year 2011/2012 with definition funding starting in September 2012. The current proposed delivery timeframe for the facilities and the simulators is 2015 to 2016.

The envisioned training focus will be on procedural drills, driving tasks (including avoiding rollover), gunnery and crew coordination as well as networked platoon, company and combat team operations for force-on-force engagements. There is a desire to accomplish as much training as is feasible and cost effective in the simulator but with minimal transition costs to field training. The project proposes to network simulators among the bases, but there are no current plans for international or joint training within these facilities.

The Directorate of Land Requirements (specifically DLR 6-5-1) has approached Defence Research and Development Canada (DRDC) to provide technical advice and propose scientific studies to resolve questions concerning the simulator requirements necessary to achieve the training objectives. The LVCTS Letter of Interest (LOI) published by DLR expressed a desire for three levels of simulator fidelity: High, Medium and Low. There is a need to determine how different technologies and representations affect training effectiveness so that each of these fidelity labels may be defined by specific technical requirements suitable for an acquisition contract.

There is a tendency when acquiring simulators to seek the most “fidelity” affordable in the belief that this will equate to the best training system affordable; however, this “naïve realism” (Smallman, Cook, Manes & Cohen, 2007; Smallman & St. John, 2005) approach may not afford any increase in training effectiveness and may actually create a less effective training environment. The LVCTS project is adopting an “informed consumer” stance in an attempt to determine where simulation fidelity provides cost effective training transfer in order to make rational choices amongst competing capabilities.

2 DRDC involvement

The Directorate Science and Technology Land (DSTL-3) has posed the following 4 questions that bear on the overall project definition before contracting should begin:

1. What is needed for definition criteria?

2. How can the proposed systems be evaluated; what acceptance criteria are both feasible and meaningful for contract evaluations?

3. What can be accomplished in a simulator to validate bids or procurement milestone deliverables?

4. What capabilities does the final system need to have to meet the desired training objectives?

Points 2 and 3 above seem tightly coupled and could be addressed by similar methods, or at least make use of common elements. Point 1 should follow from Point 4, but detailed criteria will be hard to establish without first establishing, at least at a high level, the types of activities that will take place in the simulators. At the moment, there is no firm statement of exactly what sorts of tasks are being targeted for training other than armoured tasks writ large, as this is typically outlined later in projects during the Training Needs Analysis (TNA).

There are a number of specific questions related to Point 4 that may be resolved by directed study within existing simulators, possibly with the collaboration of international allies. DLR has already contacted relevant United States (US) of America military organizations and has initiated discussions with them about lessons learned from existing US training simulators. DLR is also aware of other North Atlantic Treaty Organization (NATO) allies with similar interests in simulator-based land training.

The objective of this report is to propose areas of scientific investigation or technical advice that are thought to be relevant to the LVCTS LOI publication so that DLR may select those areas it feels important to explore further in the requirements definition phase of the LVCTS project.

Estimates of the cost and time required for each task are included in the description of the task. The cost estimate does not include any costs associated with operating military vehicles or modification to existing simulators that would be used in the trials. There is considerable uncertainty in the cost estimate, particularly estimates for work that could be done collaboratively with allied research facilities as facility costs are unknown. Proposed experimental studies generally adopt a Forward Training Transfer framework (Roscoe, 1971) although some also include a Reverse Training Transfer framework (AGARD, 1980) to provide a measure of the expected effectiveness of the training device. Sample cost estimate breakdowns that were used to develop task cost estimates are included in **Appendices** A and B for reference.

Possible areas DRDC Toronto could contribute:

1. Training Needs Analyses (TNA)

While a full TNA (Barbazette, 2006; Helander, 2006, pp. 273-292, Chapter 15) may not be appropriate at this point, elements of it would be useful in the definition phase and could serve as input to a subsequent complete TNA at a later point in the project. Specifically, high-level Job and Task analyses (Annett & Stanton, 2000) that can be used to identify the overall training objectives, task and activity demands for the various vehicles and occupations would be useful for establishing evaluation criteria for the project. The objective of this preliminary TNA would be to identify the high level technical requirements of the training rather than low level details of how the training is to occur:

a. Purpose and scope

b. Occupations to be trained

c. Type and level of training for each occupation

d. Functional capabilities to be trained

i. Tasks required for each functional capability

a) Goals

b) Methods

c) Information flow

d) Activity

i) Categorized task ability and skill requirements

The products of this preliminary TNA would be of use during subsequent analysis and training plan development by Training Development Officers (TDO). The intent would be to do a high level analysis (not a training plan) that would not require the full attention of a TDO. However, this activity would benefit from TDO guidance to define the content and format of the resulting data to support subsequent TNA activities. This preliminary TNA would require:

a. Access to Subject Matter Experts (SMEs) within each occupation or existing TNAs relevant to armoured operations

b. Access to TDOs

c. Access to Qualification Standards (QSs) and existing Training Plans (TPs) for each occupation through the Combat Training Centre (CTC) Documentium

The proposed preliminary TNA activities would be conducted under contract to a Human Factors consulting company with expertise in both CF armoured operations and the analysis of jobs and tasks. Documenting and decomposing the principal tasks to be trained for each of the occupations and platforms would require several weeks of effort of a contractor team over the course of a number of months and would cost an estimated $100,000 CAD.

2. Simulator effectiveness assessment.

   A review of the TNA and an assessment of likely technology components of the proposed three levels of simulator fidelity could be performed to estimate which tasks could likely be trained in each, given a match between the task characteristics and the simulator capabilities. Specific tasks that are thought to be on the boarder between simulator levels could be studied experimentally to determine the efficacy of the various simulators on training transfer in order to determine the appropriate mix of simulators to achieve the overall armoured vehicle training objectives. Preparation of such a study would address some of the questions associated with Point 3 (page 2 above). This may be a long term study if it is to be done with the delivered simulators, however, some insight may be provided to the definition phase if collaboration with allied laboratories could be arranged that provides access to simulators with the envisioned levels of detail.

   Such an investigation would focus on determining Transfer Effectiveness Ratios that would allow DLR to conduct cost - benefit analyses of various simulator facility configurations compared with current practice. It would also provide evidence of the expected benefit of each simulator fidelity level, although selection of appropriate tasks would be critical to ensure that the evaluation was sensitive to the simulator fidelity and experimental task, yet still be relevant to the training objectives.

   Such a study would start with a literature review to determine what relevant information currently exists. If the literature review fails to adequately describe the expected outcomes, an experimental study would be necessary. A Forward or Quasi Forward Transfer of Training experiment for a selected task or a small set of tasks would be proposed for a joint study with allied laboratories.

   Such a study would require 20 to 30 armoured personnel who require training in the task to participate as subjects; if the task selected is based on crew performance, then 20 to 30 armoured crews would be required. Half of the subjects would perform the task using existing training methods with operational equipment (or an advanced simulator in a Quasi Forward study) while the other half would receive training first with the mid-level simulator with a transition either to operational equipment (or the advanced simulator), and the resulting performance metrics of the two groups would be compared.

   The duration of the study would depend upon the availability of resources (equipment and personnel) and the experimental task(s) selected for study. It may be feasible to coordinate such a study with planned training of armoured personnel. The time to conduct such a Forward Transfer of Training study is approximately 2 months after configuration of the simulators for the selected task, assuming uninterrupted availability of subjects and simulators or vehicles. If the study were conducted with CF personnel and equipment, the cost is estimated to be approximately $80,000CAD. Note that this figure does not include any costs associated with development or modification of existing simulators, nor does it include costs associated with the operation of CF military vehicles required by the study. If an international collaborative Forward Transfer of Training study were conducted with foreign personnel, the cost could be in excess of $145,000CAD for a similar study, with an additional cost associated with renting simulator or vehicle facilities. There is considerable uncertainty

in these figures as no data are available on the cost of foreign simulator usage or foreign personnel costs at the time of this report.

3. Motion base requirements

The need for motion bases in vehicle simulators for training has been debated and researched extensively in aircraft simulators; little research has been done on land vehicle simulators, although many driving simulators incorporate some level of motion. There is little data that supports the effectiveness of motion in training simulators except for very specialized tasks and unique conditions (Bowen, Oakley & Barnett, 2006; Bürki-Cohen, Soja & Longridge, 1998a, 1998b; Jacobs, 1976; McCauley, 2006). Unfortunately, there is a lack of scientific investigation of the effectiveness of motion in ground vehicle training simulators, although there is evidence that the use of driving simulators can improve performance in the field (Coutermarsh, MacDonald & Shoop, 2011). Traditional large motion bases can be expensive and add an element of risk when using the simulator; smaller, electric motion bases are more affordable but still present an element of risk.

While the cost of electric motion bases are less than hydraulic, they are still an expense that requires supporting structures and maintenance while increasing operator risk. If simulated motion is determined to be important to learned performance transfer for tracking or continual compensation, there are many implications that will affect the level of detail in the simulator modelling that will be required: modelling of the vehicle dynamics, modelling of the ground-suspension interaction, control dynamics, modelling of specific terrain (not random disturbances). If, however, motion is primarily required for user acceptance or merely as a cueing stimulus, the implications are reduced and alternate technologies could serve a similar purpose at a lower cost and risk, such as vibrating seats or even simpler motion bases.

It is important to understand the requirement for motion in the envisioned systems so that the selection of various options is based on an evidence-based, informed decision.

The importance of motion cues in a simulation environment has been thought to depend on the complexity of the manoeuvre or task one wants to simulate (Repa, Leucht & Wierwille, 1982). Motion cues have been found to have a strong influence on the perception of speed, which might be related to the fact that humans have limited ability to detect speed changes (i.e., acceleration) when using only visual inputs (Monen & Brenner, 1994). Gracio et al. (2011) conducted a study in a simulator where they investigated the role of motion feedback for mastering skills in the driving simulation (Motion versus No-Motion conditions). They found that:

1. The average speed at which the later, and more demanding, slalom sections were driven is significantly lower for the Motion condition than for the No-Motion condition. Also, the lateral acceleration peaks were higher for the No-Motion condition. This indicates that the subjects changed their driving strategy when motion feedback was present.
2. In the Motion condition, the additional energy [derived by Fast Fourier Transform (FFT) analysis of the steering responses] is not present, which is probably because the lateral force feedback helps drivers to have more precise control inputs.

3. Motion sickness was more frequent in the No-Motion condition. The No-Motion condition was more sickening than the Motion condition. This would match theory of Groen and Bos (2008), who state that simulator sickness arises from the difference between the simulator motion and the expected motion.

Whether or not these observations have implications for training remains unclear as there is little evidence that motion sickness (and presumably simulator sickness) adversely affect performance; that is, people are able to cope despite the discomfort.

A question of interest is “Does the training effectiveness of a motion base offset the costs and risks associated with its use?” If the answer is “Yes”, then a follow-up question is “What level of fidelity needs to be incorporated in the motion simulation to achieve effective training?”

In order to address these questions, a study could be conducted to assess the efficacy of different levels of motion base fidelity on training transfer for Drivers, Crew Commanders and possibly Gunners (addressing Point 4, page 2 above) to assess the cost - benefit to determine the level of representation required. To limit the level of effort, select tasks could be proposed for further decomposition to determine if there is commonality of effects that could be used to constrain the study, focussing on those tasks thought to be most sensitive to the perception or reaction to motion.

A cross-over Reverse-Forward training transfer study would be proposed using a motion base and a simulation to investigate how the simulated vehicle motion affects learning. This study could make use of a refitted Light Armoured Vehicle Crew Gunnery Trainer (LAVCGT) or an armoured vehicle driver compartment mockup either at the DRDC Future Armoured Vehicle Simulator at General Dynamics Canada (Kanata, Ontario) or within facilities at DRDC Toronto, by extending the Helicopter Deck Landing Simulator to represent ground vehicles.

This study would require 15 experienced, qualified personnel as well as 30 novices, preferably novices training for the task under study (it is assumed that this task would be for individual performance only, not crew performance.) Input would be sought from Army Learning Support Centre/Combat Training Centre (ALSC/CTC) on how long it typically takes to train the selected task. There may be an opportunity to do a joint study with TNO1 and exploit the development they have made in the development of their driving simulators.

The duration of the study would depend upon the availability of resources (equipment and personnel) and the experimental task(s) selected for study. It may be feasible to coordinate such a study with planned training of armoured personnel. The time to conduct such a study is approximately 2 months after configuration of the simulators for the selected task, assuming uninterrupted availability of subjects and simulators or vehicles. If the study were conducted with CF personnel and equipment, the cost is estimated to be approximately $170,000CAD. If an international collaborative study were conducted with foreign personnel, the cost may be in excess of $295,000CAD, although there is considerable uncertainty in this

[1] TNO, Soesterberg, The Netherlands. http://www.tno.nl/index.cfm

figure as no data are available on the cost of foreign simulator usage at this time. Note that these figures do not include any costs associated with development or modification of existing simulators, nor do they include costs associated with the operation of military vehicles required by the study.

4. Visual display requirements

   There are a number of common and emerging technologies that can be employed in simulators, from simple desktop monitors to fully immersive displays that can include CAVE-like (Cave Automatic Virtual Environment) environments or Head Mounted Displays (HMDs). All of the displays have advantages and disadvantages that may be important (or not) depending on the range of training tasks envisioned for the simulator facilities (addresses Point **4**, page 2 above).

   Once the high level TNA study (task 1 above) has been completed, the tasks and the associated cueing information will be available that can be used to assess the visual display requirements and the cost - benefit of requirements. For instance, do the envisioned tasks require target detection and identification at the actual size, range, angular subtense, shape, contrast, luminance, inter-visibility conditions and behaviour or is simple stimulation of recognition sufficient to lead to training on the procedures and tasks that should follow?

   Typical types of questions that would be investigated would include: “Is it realistic to expect detection and identification of objects under realistic field conditions given the current state of visual displays?”; “Should synthetic environments attempt to replicate the physical, visual environment to moderate visibility?”; “What is the cost of simulator displays that can accurately display these conditions and how can the conditions be quantitatively validated?”. Alternatively, one might consider: “What are the costs associated with ignoring the detailed physical representations in simulations, being content with just having targets that are readily perceived so that they can stimulate trainees to react with appropriate procedures?”

   The answers to these questions have implications for the resolution required to detect objects under various terrain or flora conditions, the general Field of View (the extent to which the operator can see visual information with no head movement) or Field of Regard (the area within which the operator can potentially see visual information if head and body motion are allowed) required for each workstation, and the level of physical detail required of the model textures, all of which will drive computing requirements for Image Generation. They also have computational implications for the representation of sights and vision aids that may employ physics - based simulations that require detailed, transient physical properties: “Do we need to capture and display thermal infra red (IR) signatures using physics-based models interacting with sensor models or is it sufficient to present an ‘IR-sensor appearance’ of the visual scene?”

   Most of the work in this task would include consulting the literature and applying what is known about human capabilities to the tasks and scenarios entailed in the envisioned training programs. The task would require approximately 1 month of an intermediate human factors consultant’s time assuming that the TNA provides sufficient detail that the visual task demands can be readily determined. This work would cost approximately $30,000 to $40,000CAD.

5. Auditory stimulus requirements

Operations within armoured vehicles are noisy; events are often accompanied by auditory feedback; communication within and between vehicles is often auditory (via radio) although there is also a flow of visual information that communicates other vital information, particularly for command and control. But the answer to the question of "Is noise required to train for armoured operations?" is less clear. For the purpose of this paper, "noise" is considered to refer to auditory signals generated by the operation of the vehicle.

Noise is generally considered to be a distractor, which is often not desirable in a learning environment as it distracts the student from the learning objectives. If the subject cannot adapt to the noise (either physiologically, behaviourally or perceptually) then there seems little training rational for including noise in the simulation. Meanwhile, there are significant challenges associated with the introduction of noise into a simulation that has similar characteristics to that of an armoured vehicle, risks that need to be considered early in the design phase: hearing protection for students; hearing protection for instructor operators; sound isolation for simulator rooms; interference with speech recognition systems.

The use of sound in simulators is often touted as important to providing a sense of immersion, although the link between immersion and training transfer is tenuous with little empirical support. Nevertheless, if sound improves user acceptance such that effective simulators are used, then the research question should really be "How much auditory fidelity is required to promote user buy-in?" If inclusion of noise is related more to user acceptance, then perhaps less intensive implementations may be employed with consequent reduction of risk and cost. Determining the need for sound in the simulation addresses Point 4 (page 2 above) and would allow DLR to assess the cost - benefit of various levels of sound as well as the risk associated with operating in a high noise environment versus training transfer.

The noise (and possibly recoil) associated with main gun firing has been observed to induce a physiological reaction and associated performance decrement in tank gunnery (Magee, Darvill & Sweeney, 1988); this startle reaction is present even if the gun does not fire and it can cause the gunner to inadvertently move the targeting point. It is not clear whether or not it is possible to train to suppress the anticipated reaction. If it is not possible to condition the users to the noise, then it may be possible to train to compensate for it through altered behaviour (if reaction is consistent) or by modifying the Fire Control System (by filtering inputs immediately preceding firing), which would not require the inclusion of potentially dangerous levels of noise in the simulation.

If, however, users rely on auditory signals for meaningful feedback, there are significant implications for the level of detail that will be required of models. If the evidence supports the notion that noise is an important source of information that changes learning or adaptation, what kinds of noise events are useful? Is impact noise when taking fire important to learning that one is taking fire and from what direction; does it improve learning reactive procedures or does it simply serve as an alerting function? Is general background noise important to training for tasks in a noisy environment just because the real world task environment is noisy (Smallman et al., 2007; Smallman & St. John, 2005)?

For instance, if drivers rely on changes in engine noise to determine how to control the vehicle, do they use the noise for a general awareness that a control action has resulted in a vehicle response (an alerting function: Jacobs, 1976) or do they relate specific sounds to specific conditions (a tracking function: Jacobs, 1976)? The alerting function representation likely requires little in the way of fidelity, while the tracking function representation implies significant effort may be required to match control inputs with vehicle responses, including external influences such as terrain, load, etc.

Auditory noise is known to adversely affect verbal communications, decreasing the Signal/Noise ratio. Can people adapt to lower Signal/Noise ratios to reliably extract meaningful information? At what level of Signal/Noise does communication effectively fail? Could alternative methods be used to obtain an equivalent Signal/Noise ratio that lead to an equivalent acquisition of skill at extracting information (the signal) without experiencing potentially injurious levels of sound pressure (from the noise)? Will learning to detect the message in a low Signal/Noise environment occur quickly in the actual vehicle, such that experiencing it in the simulator provides little benefit?

To determine whether or not training within a realistic noise environment has benefit over training in a quiet environment, a Forward Training Transfer study could be conducted with 2 cadres of subjects to determine the effect of noise distraction in reducing training effectiveness versus real world noise fidelity. Each cadre would train in a simulator a fixed number of times or *to criterion* (a set standard that indicates the minimal acceptable performance level for qualification in a skill), then move to a field test on the same task set and train *to criterion*. Each cadre would require a group of 10 - 15 subjects, preferably of inexperienced personnel awaiting training in the target domain, with the intention of augmenting formal training to exploit the use of instructors and field equipment. It is assumed that the task selected would be based on individual performance only, not on crew performance.

The task selected for the scenario would be one that was judged to be both sensitive to noise and that had the potential for adaptation to noise. The same simulation physical environment would be used under two conditions (with noise and without noise) until they reached proficiency; they would then be tested under field conditions until criterion or until it was deemed that they would not meet criterion in a reasonable time by instructors.

The duration of the study would depend upon the availability of resources (equipment and personnel) and the experimental task(s) selected for study. It may be feasible to coordinate such a study with planned training of armoured personnel. The time to conduct such a study is approximately 1 month after configuration of the simulators for the selected task, assuming uninterrupted availability of subjects and simulators or vehicles. If the study were conducted with CF personnel and equipment, the cost is estimated to be approximately $80,000CAD. If an international collaborative study were conducted with foreign personnel, the cost may be in excess of $145,000CAD, although there is considerable uncertainty in this figure as no data are available on the cost of foreign simulator usage at this time. Note that these figures do not include any costs associated with development or modification of existing simulators, nor do they include costs associated with the operation of military vehicles required by the study.

3 Conclusion

To summarize, the objective of the proposed tasks is to provide DLR with information that can be used to make informed decisions in the specification of requirements for the Land Vehicle Crew Training System (LVCTS). Five (5) general tasks were identified for which DRDC Toronto could provide scientific support, either in the form of experimentation or contractual services. The first task would be to conduct a high level job or task analysis that would support the other four tasks as well as providing input to a formal Training Needs Analysis (TNA). This task would be conducted under contract by industry.

The second task would attempt to determine the range of tasks that could reasonably be expected to be trained in the envisioned systems in order that DLR could make a determination of the appropriate combination of devices to be specified. This would be achieved by conducting an experimental study, likely in collaboration with allied partners, using simulators of similar fidelity to those envisioned for the LVCTS.

The remaining three tasks would study the requirements for motion bases, visual display properties and auditory noise environment through transfer of training experiments using existing simulators, either within DRDC or in collaboration with our allies. All of the 4 experimental studies will require commitment of personnel as subjects, preferably military personnel awaiting training in upcoming training serials for the armoured vehicle domain to capitalize on the availability of instructors and physical resources.

The time and cost (Canadian dollars) estimates to conduct this work are summarized in the following table:

Task	Description	Duration (month)	Domestic Cost	International Cost
1	Training Needs Analisys (TNA)	6	$ 100,000	n/a
2	Simulator effectiveness assessment	2	$ 80,000	$ 145,000
3	Motion base requirements	2	$ 170,000	$ 295,000
4	Visual display analysis	1	$ 40,000	n/a
5	Auditory noise interference	1	$ 80,000	$ 145,000

The total time required to complete all of the identified work items is estimated to be 12 months if each task is conducted independently of the other tasks, although some tasks could be conducted simultaneously. Additional time may be required to prepare simulators for the experimental task or to coordinate vehicle availability.

The total cost estimate to complete all of the work would be $470,000CAD (domestic) to $725,000CAD (international collaboration), depending upon where the studies are conducted. These values do not include costs to operate military vehicles nor to modify simulators to meet the experimental objectives (if required, this would be an additional expense.)

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Appendix A. Cost estimate ($CAD) for Transfer of Training studies (domestic)

Transfer of training cost estimate (domestic experiment; Reverse and Forward Studies)						**$165,750.00**
	Item	**Reason**	**Cost/unit**	**Units**	**Cost**	**Subtotal**
Experimental Support						$ 124,250
Reverse Transfer of Training						$ 64,875
	Junior HF Specialist	Conduct experiment (1 week for Pilot Study at DRDC Toronto (10-15 subjects), 3 weeks at experiment site (20-30 subjects) ~ 15 plus 5 (unforseen events) days @ 8h/day plus)	$ 150	200	$ 30,000	
		Data collation and reduction, report (15 days)	$ 150	120	$ 18,000	
		TD at the experiment site and DRDC Toronto (hotel and per diem)	$ 225	25	$ 5,625	
		travel transportation costs (rental car)	$ 50	25	$ 1,250	
		travel transportation costs (2 airfare @ $1000 ea)			$ 2,000	
	Contractor PM	Contract oversight charges (fixed costs)			$ 2,500	
	HEEC Engineer	Experiment setup - 1 week of TD at the experiment site	$ 225	5	$ 1,125	
		travel transportation costs (airfare)			$ 1,000	
		travel transportation costs (rental car)	$ 50	25	$ 1,250	
	HEEC Engineer	Experiment setup - 1 week of TD at the experiment site	$ 225	5	$ 1,125	
		travel transportation costs (airfare)			$ 1,000	
Forward Transfer of Training						$ 59,375
	Junior HF Specialist	Conduct experiment (4 weeks at experiment site ~ 5 prep days, 15 testing plus 5 (unforseen events) days @ 8h/day plus) for 20-30 subjects	$ 150	200	$ 30,000	
		Data collation and reduction, report (15 days)	$ 150	120	$ 18,000	
		TD at the experiment site and DRDC Toronto (hotel and per diem)	$ 225	25	$ 5,625	
		travel transportation costs (rental car)	$ 50	25	$ 1,250	
		travel transportation costs (2 airfare @ $1000 ea)			$ 2,000	
	Contractor PM	Contract oversight charges (fixed costs)			$ 2,500	

Experiment Costs						$ 41,500
Reverse Transfer of Training						$ 22,250
	Subject Pay for Reverse TOT	45 Subjects (15 for pilot, 15 naïve, 15 expert) -- note: could be 45 crews (of 4) depending upon task	$ 50	180	$ 9,000	
	Incidental costs	experiment supplies purchased at destination			$ 250	
	Principal Investigator	TD at the experiment site (hotel and per diem)	$ 225	20	$ 4,500	
		travel transportation costs (2 airfare @ 1000)			$ 2,000	
	Co-investigator	TD at the experiment site (hotel and per diem)	$ 225	20	$ 4,500	
		travel transportation costs (2 airfare @ 1000)			$ 2,000	
Forward Transfer of Training						$ 19,250
	Subject Pay for Forward TOT	30 Subjects (15 control, 15 experimental) -- note: could be 30 crews of 4 depending upon task	$ 50	120	$ 6,000	
	Incidental costs	experiment supplies purchased at destination			$ 250	
	Principal Investigator	TD at the experiment site (hotel and per diem)	$ 225	20	$ 4,500	
		travel transportation costs (airfare)			$ 2,000	
	Co-investigator	TD at the experiment site (hotel and per diem)	$ 225	20	$ 4,500	
		travel transportation costs (airfare)			$ 2,000	

Note:
HF: Human Factors
HEEC: Human Effectiveness Experimentation Centre, Defence Research and Development Canada (DRDC) Toronto
PM: Project Management
TD: Temporary Duty
TOT: Transfer of Training

Appendix B. Cost estimate ($CAD) for Transfer of Training studies (international collaboration)

Transfer of training cost estimate (international collaborative experiment; Reverse a						**$291,500.00**
	Item	**Reason**	**Cost/unit**	**Units**	**Cost**	**Subtotal**
Experimental Support						$ 212,000
Reverse Transfer of Training						$ 106,000
	Simulator plus technician	Conduct experiment (3 weeks at experiment site ~ 15 plus 5 (unforseen events) days)	$ 2,000	20	$ 40,000	
	Technician	Data collation and reduction, report (15 days)	$ 250	120	$ 30,000	
	Collaborator PI	Oversight	$ 300	120	$ 36,000	
Forward Transfer of Training						$ 106,000
	Simulator plus technician	Conduct experiment (3 weeks at experiment site ~ 15 plus 5 (unforseen events) days)	$ 2,000	20	$ 40,000	
	Technician	Data collation and reduction, report (15 days)	$ 250	120	$ 30,000	
	Collaborator PI	Oversight	$ 300	120	$ 36,000	

Experiment Costs						$ 79,500
Reverse Transfer of Training						$ 42,750
	Subject Pay for Reverse TOT	45 Subjects (15 for pilot, 15 naïve, 15 expert) -- note: could be 45 crews (of 4) depending upon task	$ 100	180	$ 18,000	
	Incidental costs	experiment supplies purchased at destination			$ 250	
	Principal Investigator	TD at the experiment site (hotel and per diem)	$ 350	30	$ 10,500	
		travel transportation costs (airfare)			$ 4,000	
		travel transportation costs (rental car)	$ 150	30	$ 4,500	
	Co Investigator	TD at the experiment site (hotel and per diem)	$ 350	10	$ 3,500	
		travel transportation costs (airfare)			$ 2,000	
Forward Transfer of Training						$ 36,750
	Subject Pay for Forward TOT	30 Subjects (15 control, 15 experimental) -- note: could be 30 crews of 4 depending upon task	$ 100	120	$ 12,000	
	Incidental costs	experiment supplies purchased at destination			$ 250	
	Principal Investigator	TD at the experiment site (hotel and per diem)	$ 350	30	$ 10,500	
		travel transportation costs (airfare)			$ 4,000	
		travel transportation costs (rental car)	$ 150	30	$ 4,500	
	Co Investigator	TD at the experiment site (hotel and per diem)	$ 350	10	$ 3,500	
		travel transportation costs (airfare)			$ 2,000	

Note:
- HF: Human Factors
- HEEC: Human Effectiveness Experimentation Centre, Defence Research and Development Canada (DRDC) Toronto
- PM: Project Management
- TD: Temporary Duty
- TOT: Transfer of Training

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.) Defence R&D Canada – Toronto 1133 Sheppard Avenue West P.O. Box 2000 Toronto, Ontario M3M 3B9	2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.) UNCLASSIFIED (NON-CONTROLLED GOODS) DMC A REVIEW: GCEC JUNE 2010

3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Proposed scientific support to the Land Vehicle Crew Training System (LVCTS) project requirements definition

4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used)

Cain, B.; Zotov, V.

5. DATE OF PUBLICATION (Month and year of publication of document.) January 2013	6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.) 30	6b. NO. OF REFS (Total cited in document.) 0

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Technical Memorandum

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

Defence R&D Canada – Toronto
1133 Sheppard Avenue West
P.O. Box 2000
Toronto, Ontario M3M 3B9

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.) 14dn	9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)
10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.) DRDC Toronto TM 2011-156	10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (Any limitations on further dissemination of the document, other than those imposed by security classification.)

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The Land Vehicle Crew Training System (LVCTS) is a proposed acquisition of a variety of armoured vehicle simulators for training within the Canadian Forces. The Directorate of Land Requirements (DLR) has published a Letter of Interest (LOI) to solicit input from industry, but DLR has requested advice from Defence Research and Development Canada (DRDC) Toronto to provide evidence based determination of the simulator requirements. DRDC Toronto has proposed 5 tasks that could be undertaken to clarify requirements, based on information provided in the LOI, suitable for inclusion in a Request for Proposal. The tasks include: preliminary Training Needs Analysis; an assessment of the expected simulator effectiveness; an assessment of motion base requirements; an evaluation of visual display requirements; and, an assessment of auditory noise requirements. Estimates of the time and cost to complete these tasks are included in the report for DLR consideration.

Le système d’entraînement des équipages des véhicules terrestres (SEE VT) constitue une proposition d’acquisition d’une variété de simulateurs de véhicules blindés destinés à l’entraînement au sein des Forces canadiennes. La Direction des besoins en ressources terrestres (DBRT) a publié une déclaration d’intérêt afin d’obtenir des renseignements de la part de l’industrie tout en demandant des conseils à Recherche et développement pour la défense Canada (RDDC) Toronto afin que celle-ci lui fournisse des observations factuelles à l’égard des exigences en matière de simulateurs. RDDC Toronto a proposé cinq tâches susceptibles d’être entreprises pour clarifier les exigences, fondées sur les renseignements contenus dans la lettre d’intérêt, pouvant être incluses dans une demande de proposition. Ces tâches sont les suivantes : l’analyse préliminaire des besoins en matière d’instruction, l’évaluation de l’efficacité attendue des simulateurs, l’évaluation des exigences fondées sur le mouvement, l’évaluation des exigences en matière de visualisation et l’évaluation des exigences en matière de bruits auditifs. Des estimations du temps et des coûts pour accomplir ces tâches se trouvent dans le rapport à des fins d’analyse par la DBRT.

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simulator; training; requirements

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